Development of an energy storage database and life cycle analysis

RESTLESS
Realising Energy Storage Technologies in Low-carbon Energy Systems

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1. Context and motivation

The field of energy storage is taking on growing significance and sources of flexibility to unite energy supply with energy demand are becoming more valuable. However, in many cases the technologies that seek to provide this flexibility are not yet mature. As well as the technical challenge to develop these solutions, a parallel challenge exists in the form of uncertainty for investors, policy-makers and industry. Lack of robust knowledge and insight into what storage can do and what it will cost, both now and in the future, is one of the barriers holding back investment and informed policy.

Aim
To collate and disseminate data on the cost, performance, and life cycle environmental impacts of energy storage technologies to support decision-making.

By bringing together this data in an accessible and managed framework, the RESTLESS project set out to strengthen a wide range of further studies both within and beyond the consortium. The energy storage database is designed to provide useful insights to a range of stakeholders both during and after the RESTLESS study.

Intended audience
Each audience is likely to interact with the database in a different way, seeking different levels of detail:

- Academics: for electricity and energy system modelling, economics and policy work.
- Policy-makers: to understand which technologies show promise for particular applications.
- Companies: to undertake research and investment into new technologies.
- Storage customers: to see how different technologies are developing.

2. Approach

The primary data-gathering approach was a literature review of available industry and academic sources. The data obtained was itself derived from a range of methods, including industry estimates, expert elicitation, academic findings and existing projects. A set of metrics for energy storage cost and performance was defined and populated.

The database includes published data on:

- Rated power
- Discharge duration
- Capital costs
- Operating costs
- Roundtrip efficiency
- Calendar life
- Cycle life
- Self-discharge
- Depth of discharge
- Response time

Life cycle analysis (LCA) data was collated for the cumulative energy demand (CED) and greenhouse gas (GHG) emissions associated with each technology. Wherever possible, the context of the cost, performance and LCA measures was captured, so that effects of scale, technology maturity and others can be explored.

3. Database design

As well as being an organised repository for data, the system is designed to encourage careful use of that data. Obtaining data on energy storage technologies is challenging for several reasons, including the relative novelty of many solutions, and the broad range of parameters required to assess a given system. The system is therefore designed to be transparent about what data is available and help the user to make the best use of that data.

Challenges to data availability

- Lack of experience 'in the field'
- Rapid advances in cost and performance
- Reluctance of companies to share proprietary data
- Incomplete reporting of costs and performance metrics
- Inconsistency in how metrics are used

Design principles
A number of design principles have been laid down in response to user requirements and data challenges:

- Each record in the database has to be self-consistent
- Each record has a single cited reference
- Different levels of detail can be stored
- Summary statistics should be robust to outliers and skew
- Output needs to be viewed in multiple dimensions
- Data can be grouped by rated power and by discharge
- Simple structure for porting to web or download
- Straightforward to extend and maintain

The database has initially been developed in Excel, but is available in 'alpha' form as a web application coded with JavaScript and Google Charts.

4. Cost and performance

Mapping the capital cost per unit power and per unit energy in Figure 1 demonstrates the wide ranges spanned by different ES technologies. It is important to note that these technologies are often not direct competitors; with a variety of scales, energy densities, storage durations, and speeds of response, each is suited to particular applications.

Projecting forwards to 2030, significant cost reductions are expected for each of the battery technologies shown, most notably lithium-ion. Thermo-mechanical technologies like adiabatic compressed air energy storage, liquid air, and pumped heat show smaller cost reductions as their components are relatively simple and readily available, but should exhibit further reductions due to the use of larger systems and higher manufacturing volumes.

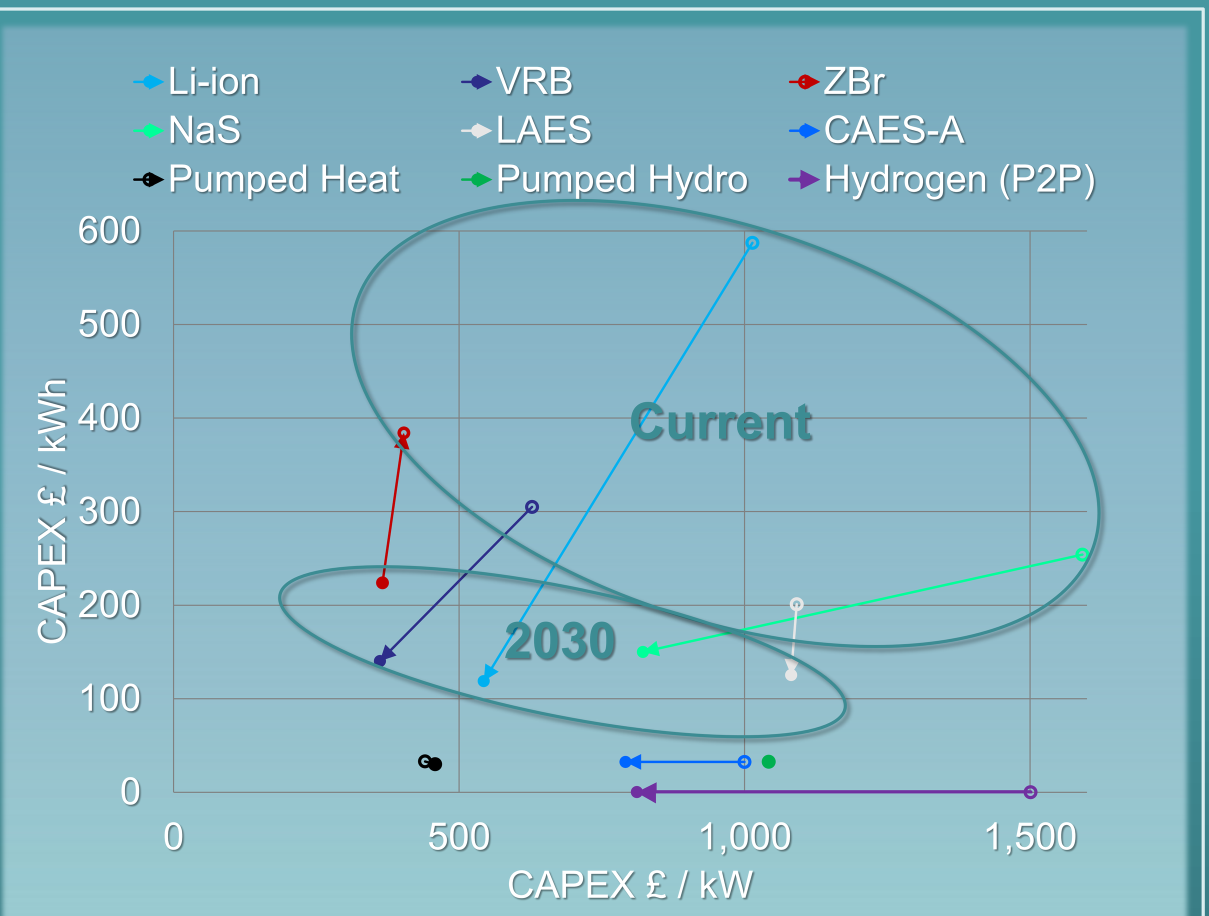

Figure 1: Averaged capital cost per unit energy and per unit power in 2010£ for ES technologies in 2016 and 2030. Li-ion – lithium-ion, VRB – vanadium redox, ZBr – zinc bromine, NaS – sodium sulphur, LAES – liquid air energy storage, CAES-A – adiabatic compressed air energy storage.

5. Life cycle environmental impacts

Cumulative energy demand is only one of many LCA considerations, but provides a useful handle on how resource intensive a technology is to produce. Each of the battery technologies in Figure 2 are found to have mean CEDs between 300 and 600 MWh_{pri}/MWh_{cap}, whilst pumped hydro and compressed air (using natural gas) show much lower CEDs. High scatter is seen in the CED estimates, even within specific variants of lithium-ion (Figure 3).

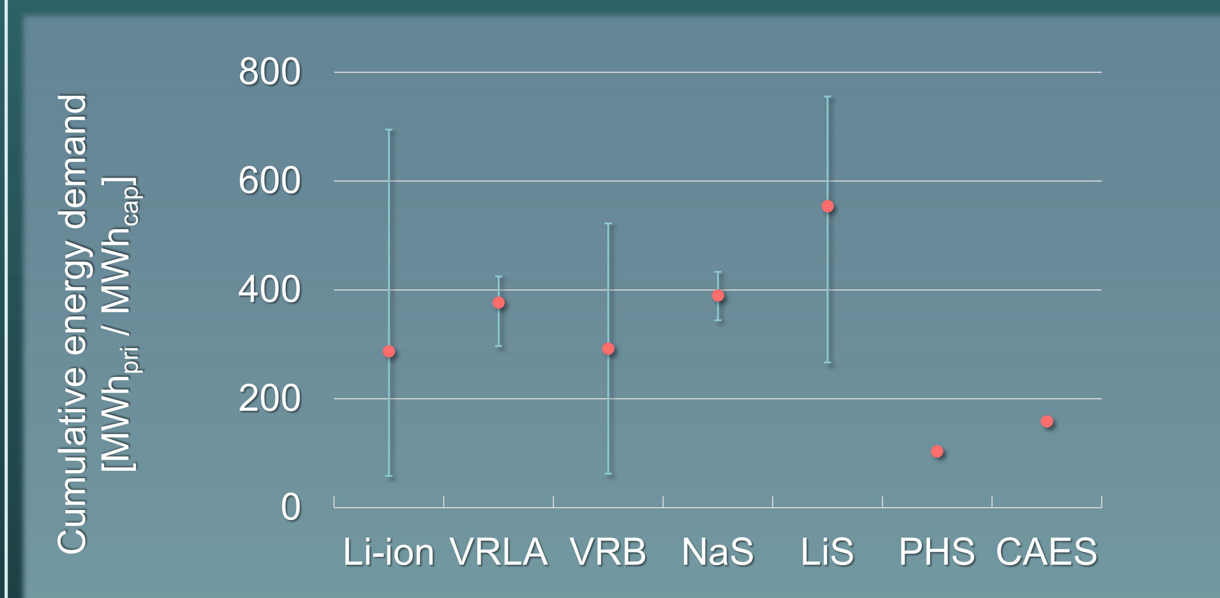

Figure 2: Cumulative energy demand (primary energy input per unit storage capacity) for a selection of ES technologies, plotted as a mean and max-min range. Li-ion – lithium-ion, VRLA – valve regulated lead acid, VRB – vanadium redox batteyr, NaS – sodium sulphur, LiS – lithium sulphur, PHS – pumped hydroelectric storage, CAES – compressed air energy storage.

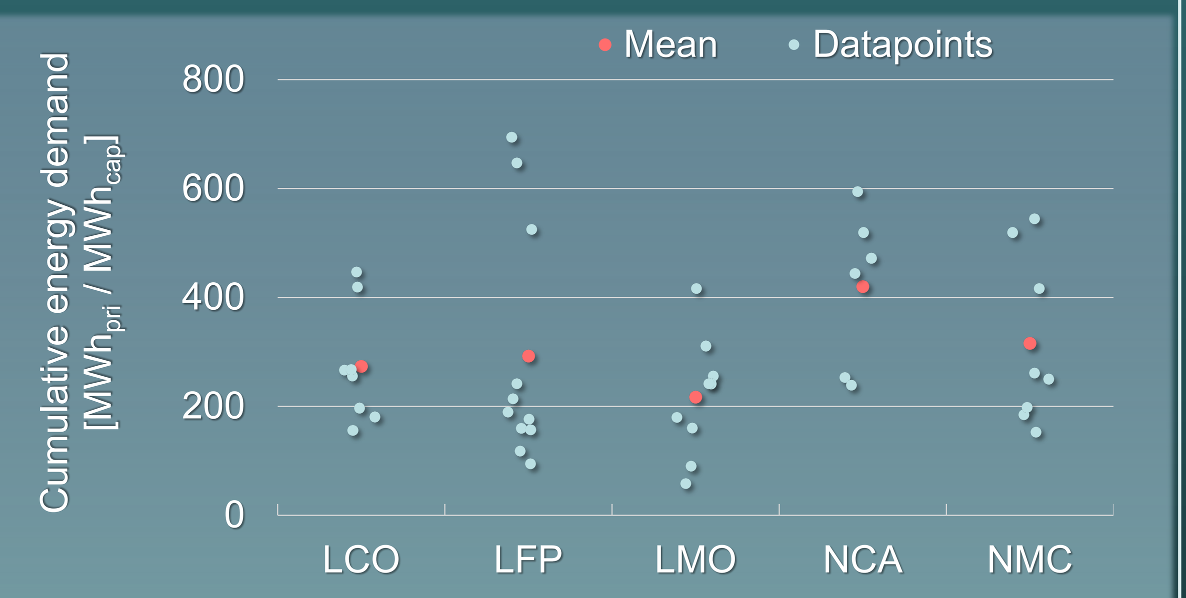

Figure 3: CED for variants of lithium-ion batteries, showing the mean value and individual data points. LCO – lithium cobalt oxide, LFP – lithium iron phosphate, LMO – lithium manganese spinel oxide, NCA – nickel cobalt aluminium, and NMC – nickel manganese cobalt.

6. Further work

While a range of data has already been collated, there remains a need to continually extend and add to the collection, both to broaden the range of covered technologies and to update estimates as technologies mature. An area of particular interest for additional data is thermal storage and power-to-fuel conversion.

The user interface to the database is currently under development and will be refined in response to feedback from a range of stakeholders. The development version can be accessed at www.restlessdb.co.uk, and feedback is warmly welcomed at restlessdb@gmail.com.

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